

ORACLES P3 Flight Scientist Post-Flight Status Report

Date: 03 October 2018

Flight number: PRF04Y18

Routine flight or target of opportunity? Target

If target of opportunity, what is the goal? Lagrangian resampling of pocket of open cells that was sampled on PRF03 on the previous day (02 Oct)

Flight scientist: Robert Wood

Assistant flight scientist: N/A

Ground scientist: Michael Diamond

Asst. Ground scientist: N/A

Take-off: 06:56:29 UT

Landing: 15:14:17 UT

Quick summary:

Representative ACAOD or ACAOD range for flight: 0.4 ACAOD, 0.45 full-column

Do the models predict crossing a gradient in aerosol age? YES (older in boundary layer, younger above)

Yes/No/Unclear

North south gradient in aerosol loading (south more dirty)

Did the flight cross a gradient in macroscopic cloud properties, like cloud fraction?

Yes/No/Unclear

Notes: Closed cells were present on the transit from Sao Tome to 5E, 7.5S. East of 6E along 7.5S, a large region of open cells was present with significantly lower cloud fraction.

Did the flight cross a gradient in aerosol loading?

Yes/No/Unclear

YES: In the PBL, the accumulation mode aerosol concentration within the pocket of open cells (POC) was very low (ultraclean conditions of just a few cm^{-3}). Further north, the PBL was clean but not ultraclean. The FT plume was extensive aloft above both the

POC and the surrounding closed cells. There was clear evidence of smoke aerosol being present immediately above the clouds in the closed and open cell regions, although the highest scattering ratios in the plume were between 2-3.5 km altitude.

At any point during the flight, was there a clear separation between the smoke plume(s) and cloud tops?

Yes/No/Unclear

Within the POC itself, there is evidence that in some places, the above-cloud air was quite clean, but in other places there are clear smoke layers immediately atop the clouds, with several hundred accumulation mode particles per cc.

How many of the following maneuvers took place?

Ramps _0_____

Square spirals __2_____

MBL legs __3 (2 in POC; 1 on 5E at 4.5S) _____

Cloud legs _2 in POC _____

Above cloud legs __1 immediately above cloud at 3800 ft; 1 in plume 5500ft_____

Sawtooth legs __2 (1 in POC; 1 on return to Sao Tome from 4.5S, 5E to 1N, 5E) _____

Plume legs __4_____

Above plume legs __outbound transit from TMS to 7.5S and towards POC sampling location;

Instrument status:

P3	No problems
4STAR	Operated well throughout flight, ACAOD about 0.4, potential of significant window deposition.
HiGEAR	Working well, submicron neph still not working bulb coming tomorrow. Need to do some cals.
HiGEAR AMS	Worked well.
RSP	Worked well. Sun was in good geometry for line on 7°E
APR3	Good day, no problem. Variety of scenes, from drizzle to heavier precipitation. Configuration confusion which was resolved
Cloud probes	Worked well. All instruments worked well. Time sync with HVPS is small issue. CIP images had little low light
CCN/Filters	Everything worked well. Saw gradients throughout that aerosol layer, All 5 filters were exposed.
PTI	Worked well. Difference in SSA with upper level slightly lower (0.83) than lower level.
PDI	No problems
Vertical winds	Looked good
WISPR	Isotopes had a great day of science. Operator was awake for most of the time. Drizzle cases are interesting. Green for next flight.
COMA	Worked well today, saw some highest and lowest CO levels seen so far in 2018.
SSFR	SPN worked well. Camera worked well. Possible light collector issue. Platform did not work whole flight. Need aircraft power to switch to diagnose platform issues.
HSRL	Good looking flight. Definitely interesting to see transition, and particularly the larger aerosol particles. Some issue about altitude scale in real time plot
data	Litton was only problem - tomorrow it will likely be fixed

PRF04Y18 date 08/03/2018 Mission Report

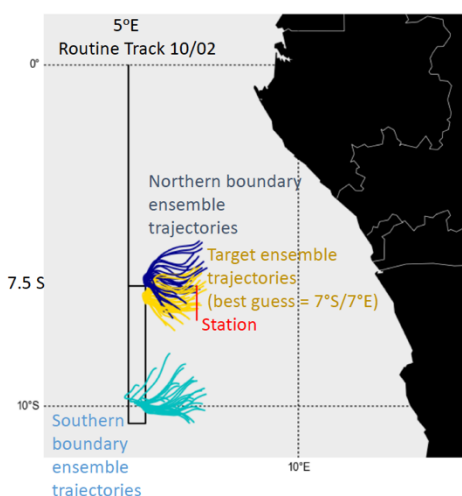
flight scientist: Robert Wood

ground scientist: Michael Diamond

Flight plan and objective:

PBL Lagrangian resampling flight to capture pocket of open cells that was sampled on the previous routine flight the day before (PRF03 08/02/2018). Lagrangian PBL trajectories were used to identify location(s) of open cellular region sampled on PRF03 (Fig. 1). A series of stacked sampling legs was flown (#1-8 on right side of Fig. 1) in a N-S/S-N direction along the line. After the POC and FT plume sampling, the P-3 flew to 4.5S, 5E before heading north, largely conducting deep sawtooth sampling through the lower troposphere to 1N, 5E.

Figure 1: Trajectory ensembles initiated from locations on northern (dark blue) and southern (cyan) boundaries of a region of open cells on PRF03 (08/02/2018). To maximize sampling time on PRF04, it was decided to resample a set of trajectories toward the northern edge of the open cell region (yellow trajectories). The red line ("station") indicates the chosen target sampling location (7E, 6.5-7.5S) for the stacked low-level POC sampling legs.



Transit to station at altitude: 2.5 hours

At station (6.5-7.5°S, 7°E): ~2 hours

1. Remote sensing leg (15 minutes N)
2. Square spiral (15 minutes)
3. Boundary layer leg (15 minutes S)
4. Above-cloud leg (15 minutes N)
5. Sawtooths (15 minutes S)
6. Level in-cloud leg (15 minutes N)
7. Lower plume leg (15 minutes S)
8. Upper plume leg (15 minutes N)

Transit home at altitude: 2.5 hours

7 hour flight as planned, so there should be some time for more science on transit back

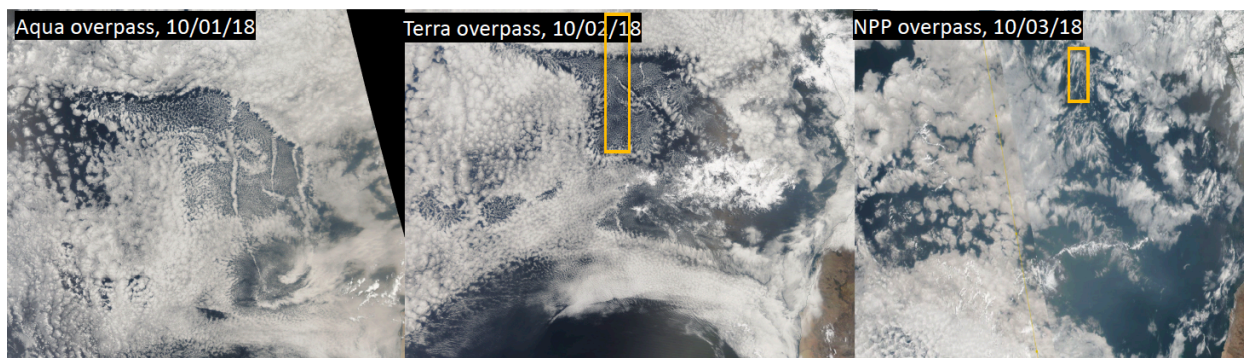


Figure 2: MODIS/VIIRS imagery from 10/01/2018 (left, 2 days before PRF04); 10/02/2018 (center, 1 day before PRF04) and on 10/03/2018 (day of PRF04). The POC is most clearly defined on 10/02 (i.e. day of routine flight PRF03). Box in center panel shows approximate locations of N-S and S-N sampling on PRF03. Sampling on PRF04 took place within the orange box on the right panel. Shiptracks can clearly be seen within the POCs. One ship track was sampled on PRF03, and was resampled on PRF04.

Flight Summary:

Transited to 5E, OS via EREGO but dodging convection close to EREGO. Top of climb at 16kft (7:12 UTC) but climbed again au 8:00 UTC to 18 then 19 kft to stay as high as possible. Transited southward on routine track to 5E to 7.5S, then turned east and headed to 7E, 7.5S to southernmost position on sampling line (Fig. 3). Aerosol layers were present in the FT all the way from the equator to 7.5S (Fig. 4), with evidence of high frequency fluctuations possibly associated with gravity waves and blobby “lava lamp” type convection (4S)

Figure 3 (right): SEVIRI image at 07:45 UTC showing location of P-3 (red X and green track) on its way southward along 5E to sample open cell region shown in red box (6.5-7.5S, ~7E).

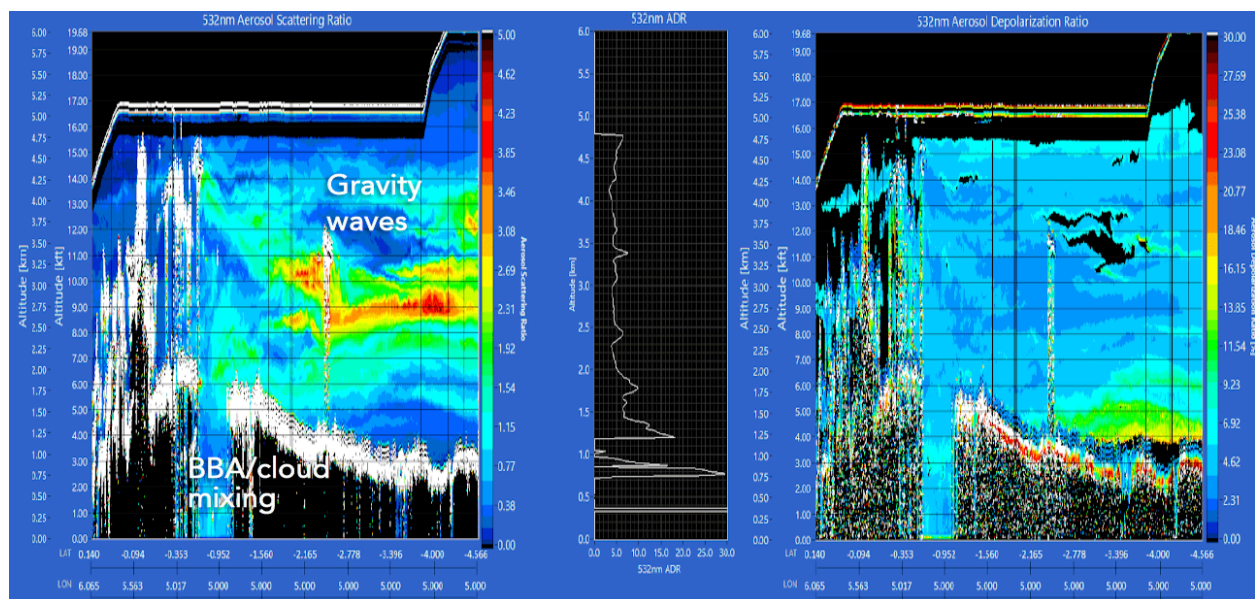
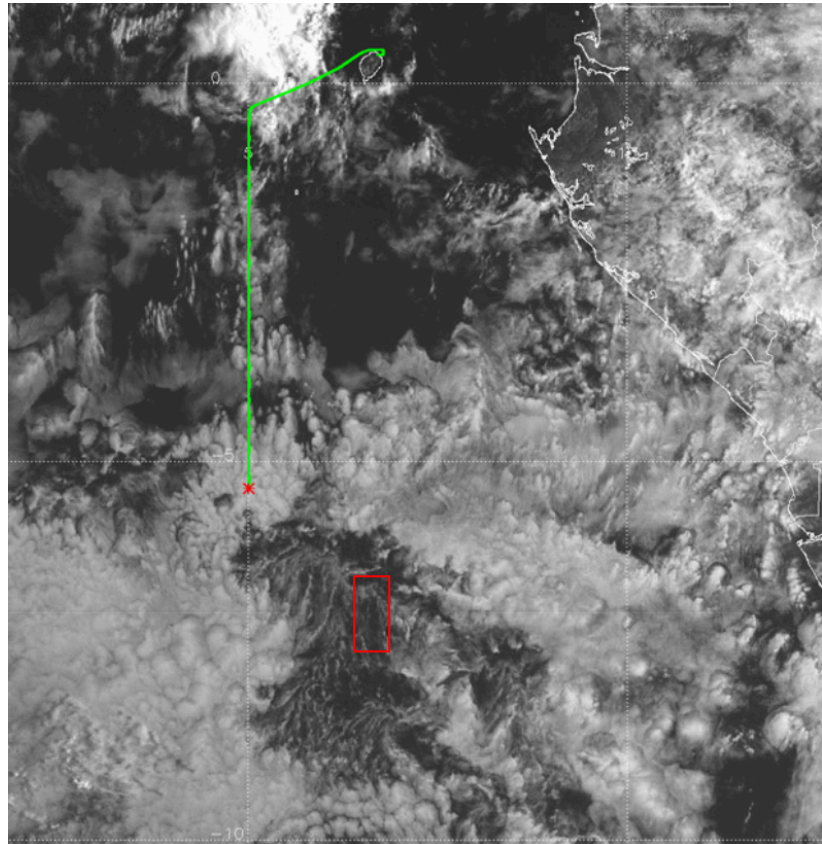


Fig. 4: HSRL aerosol scattering ratio (left) and depolarization ratio (right) at 7:45 UTC showing BBA layers throughout lower FT from 4-15 kft, with strongest scattering layers between 6000 and 13000 ft. Also, note how cloud top height rises strongly north of

3S, rising from 3000 ft to almost 6000 ft between 3S and 1S. The top of the cloud layer around 1S appears to be intersecting the FT plume that is itself sloping downward to the north.

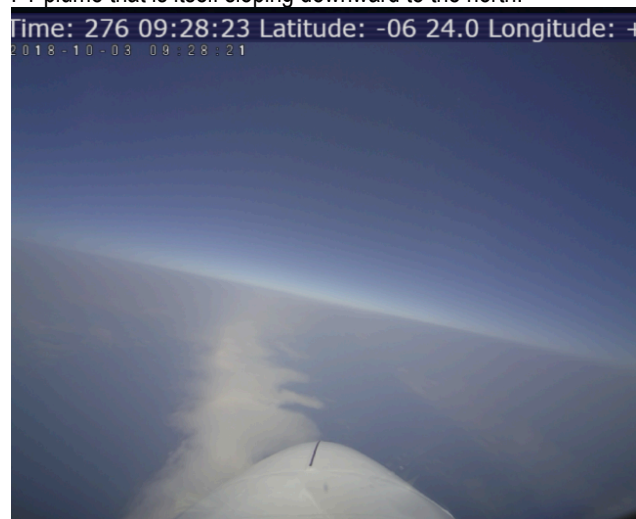
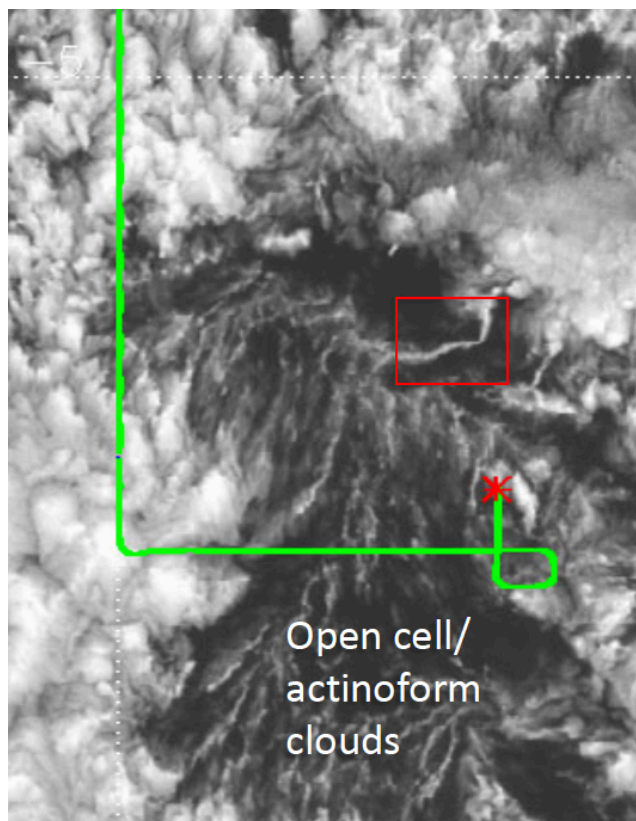


Figure 5: Above: View of low-level clouds from square spiral downward at 09:28 UTC. An extended bright line of low level stratiform clouds can be seen, which may be the vestiges of a type 1 ship track within the POC highlighted in red on 08:45 SEVIRI image (right). The band also resembles the bright arm within an actinoform cloud system.



POC low level sampling:

09:12 Arrived at southernmost sampling point. Turn 270 degrees to right to head north.

09:16 S-N remote sensing leg at 19 kft above POC (Fig. 6)

09:28 Square spiral down to 200 ft at northern end of sampling line (6.7S, 7E). Can see vestiges of type 1 shiptrack that was sampled on PRF03 and which still remained (Fig. 5).

09:44 Pass through thick cloud on square spiral down, tops 3000-3500 ft. Above-cloud AOD~0.43

09:46 Under cloud, BC is low (25ng m^{-3}), scattering $\sim 2\text{ (Mm)}^{-1}$, 70 ppbv CO, cloud base $\sim 500\text{ft}$

09:50 Near surface windspeed at 10 knots. UHSAS very low at about 10 cm^{-3}

09:57 N-S leg above cloud at 3800 ft. Considerable concentrations of large “Rose” aerosol particles observed in FT at southern end of leg, but fewer at northern end. High humidity above cloud. CCN concentrations $\sim 800\text{ cm}^{-3}$ above cloud.

10:19 End of N-S leg, turn to N for PBL leg below cloud at 200 ft altitude.

10:20 S-N leg at 200 ft. Showers observed. Evidence of large “Rose” particles in the PBL.

10:46 N-S sawtooth leg through cloud and lower FT. Cloud droplet concentrations $20\text{-}40\text{ cm}^{-3}$. Very clean in the PBL between clouds. No evidence of new particle formation, ultra-fine aerosol concentrations not strongly elevated.

11:05 S-N in-cloud leg at 2400 ft. Optically-thin veil type clouds observed associated with Cu. No new particle formation evident.

11:14 Climb to 2900 ft. Large modal diameter (30 micron) in thin detraining clouds.

11:24 End of POC sampling

Climb to 5500 ft for FT plume sampling.

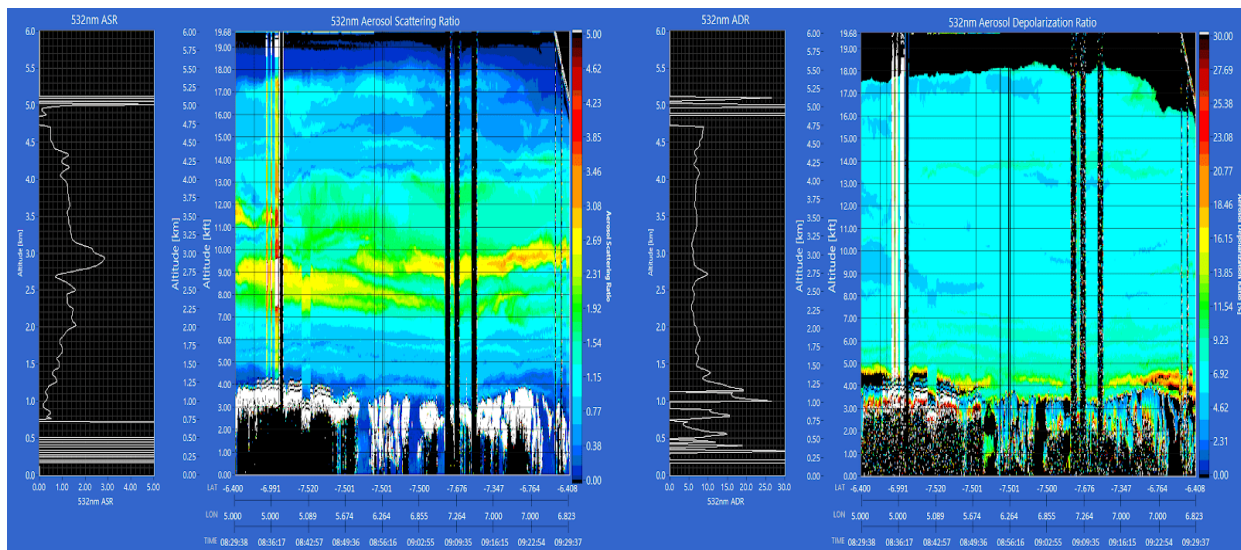


Figure 6: HSRL aerosol scattering ratio (left) and depolarization ratio (right) from remote sensing leg above the POC. The cloud top heights in the POC are 2500-3500 ft, somewhat lower than those in the surrounding closed cells (3500-4000 ft) which can be seen on the left prior to 08:48 UTC. Gaps between the Cu clouds indicate very low aerosol scattering ratios consistent with the ultraclean nature of the POC.

FT Plume Sampling:

- 11:24 Climb to 5500 ft on N-S to sample lowest clearly-defined layer within FT plume (Fig. 5). Climb to 9300 ft to find heavier aerosol loading.
- 12:01 S-N leg at 8600 ft in plume. CO ~ 300 ppbv; CN=2000 cm^{-3} ; scattering 100 $(\text{Mm})^{-1}$; ozone higher here than at lower levels. RH ~ 0.6 .
- 12:05 Continue sampling an aerosol gradient north south (more pollution in the south) even at different altitudes. Still no cirrus in area. Wet aerosol layer. $1.5 \mu\text{g}/\text{m}^3$ of BC, 300ppb of CO. 50% higher ozone.
- 12:14 In the thick of the FT aerosol plume. About 120-150 μm diameter aerosol size
- 12:18 Seems to be right between 2 airmasses (vertically) with CO and water vapor oscillating - maybe similarly to 'lava lamps'
- 12:41 On the diagonal to 5°E , 4.5S with some aerosol layers, clouds underneath are not precipitating, with varying albedos and 2 layers.
- 12:59 Climb to max altitude for square spiral from high altitude to 200 ft, likely window deposition at about 0.12, 0.07 more than previous at this altitude.
- 13:00 Square spiral down from 19000ft to 200 ft.
- 13:21 End square spiral. Midlevel clouds evident aloft, continuing to north (Fig. 7)

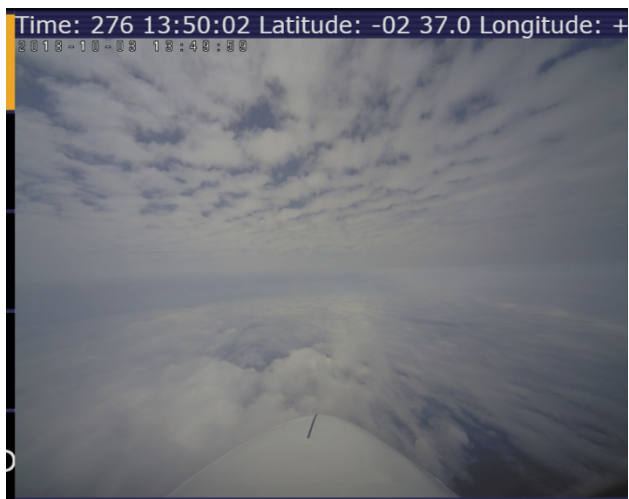


Figure 7: Right: Mid-level altocumulus clouds above aircraft on S-N sawtooth at 2.7S . Low level clouds below include banded lines of Cu and stratiform layers.

Return sawtooth:

PBL is decoupled at 4.5S, 5E. Relatively clean air mass, but not as clean as in POC. Nd is $\sim 50 \text{ cm}^{-3}$.

Deep sawtooth all the way back to 1N, 5E. PBL deepens strongly from 3S to equator, and convective clouds become stronger. Some Cu congestus and some deeper Cbs.

Forecast Conditions

CLOUDS:

48-hr forecast (Oct 02 weather/aerosol discussion) for 12:00 UTC Oct 3, 2018 shows a region of broken patchy clouds in the region to be resampled (6-8S, 7E). The GEOS model also forecasts broken clouds in this region (Fig. 8).

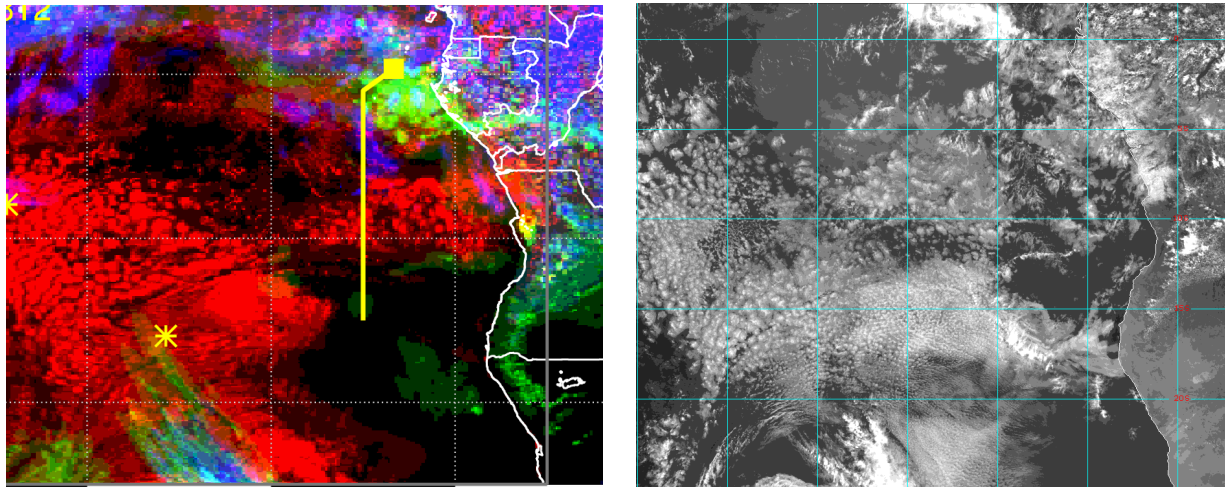


Figure 8: Forecast (left) and actual (right; high-res visible image) for 12:00 UTC on 10/03. The forecast5 shows extensive clearing of clouds south of 10S and east of 3E, but the satellite does not show as much clearing as in the forecast. The model forecast the stratocumulus sheet extending from St. Helena to Ascension Island quite well.

AEROSOLS:

Forecast AOD from the GEOS 48 hour forecast near to Sao Tome is ~ 0.1 , but this increases to 0.4-0.45 near the sampling region (Fig. 9, left). This is close to the 4STAR measured AOD of ~ 0.45 in the region. WRF-AAM shows higher AOD, most likely related to stronger hygroscopic growth under high RH environments in AAM (Fig. 9, right). ECMWF shows relatively light surface winds in the sampling region (Fig. 10). The aerosol age from WRF-AAM shows a very distinct plume boundary at approximately 2 km altitude in the sampling region, with relatively young (3-5 days) aerosol aloft, and aged aerosol (10-11 days) sitting immediately above the PBL.

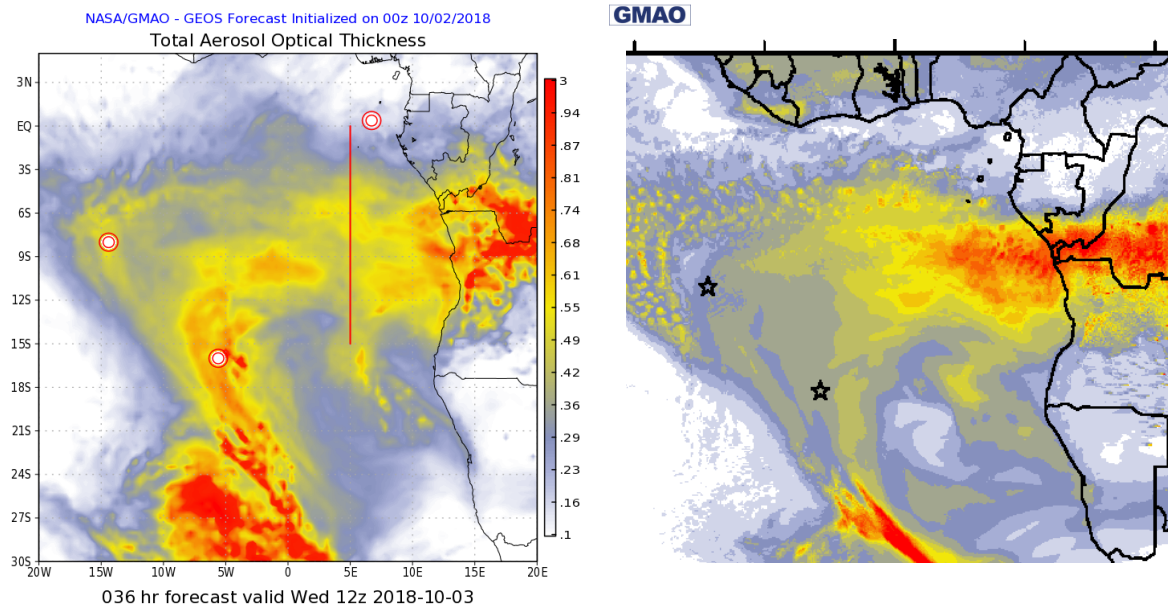


Figure 9: 48-hour AOD forecast from GEOS (left) and a more recent forecast from WRF-AAM (6 hr, since AAM was not available at planning time) for 10/03 at 12 UTC.

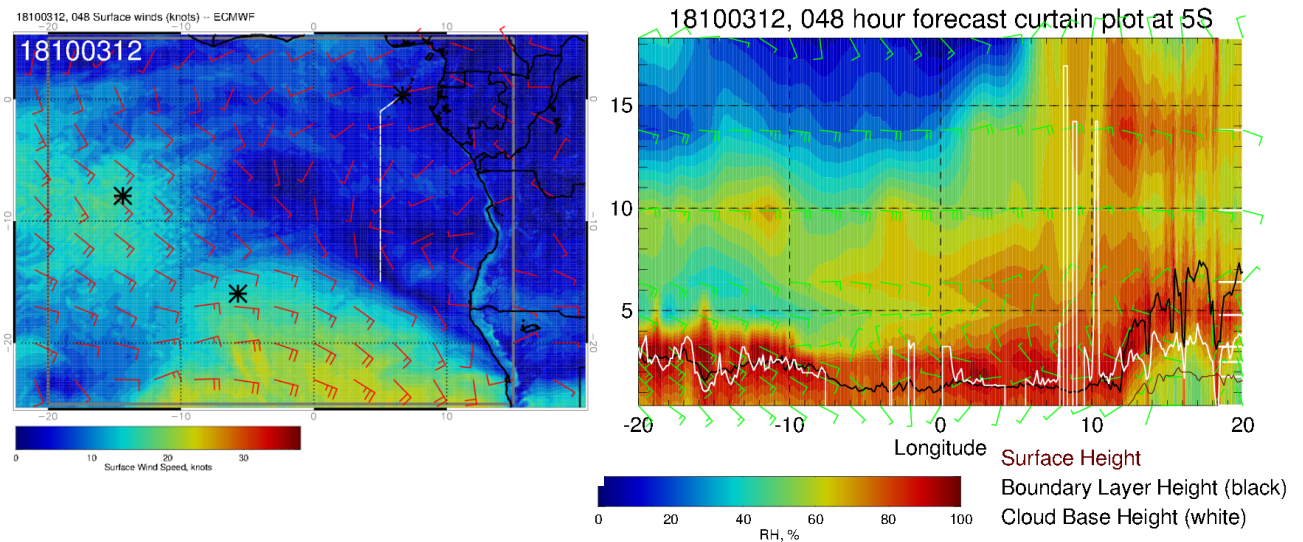


Figure 10: **Left:** Surface wind speed forecast by ECMWF showing light surface winds with a westerly component that explains why the PBL trajectories (Fig. 1) are showing eastward movement. **Right:** E-W forecast cross section showing relative humidity (colors), PBL height, and cloud base height (white). Around the sampling region (6-8E), the PBL is decoupled with evidence of Cu bases of just over 1000 ft, consistent with observed Cu bases in the POC. There is high humidity extending up to over 5000 ft in the sampling region.

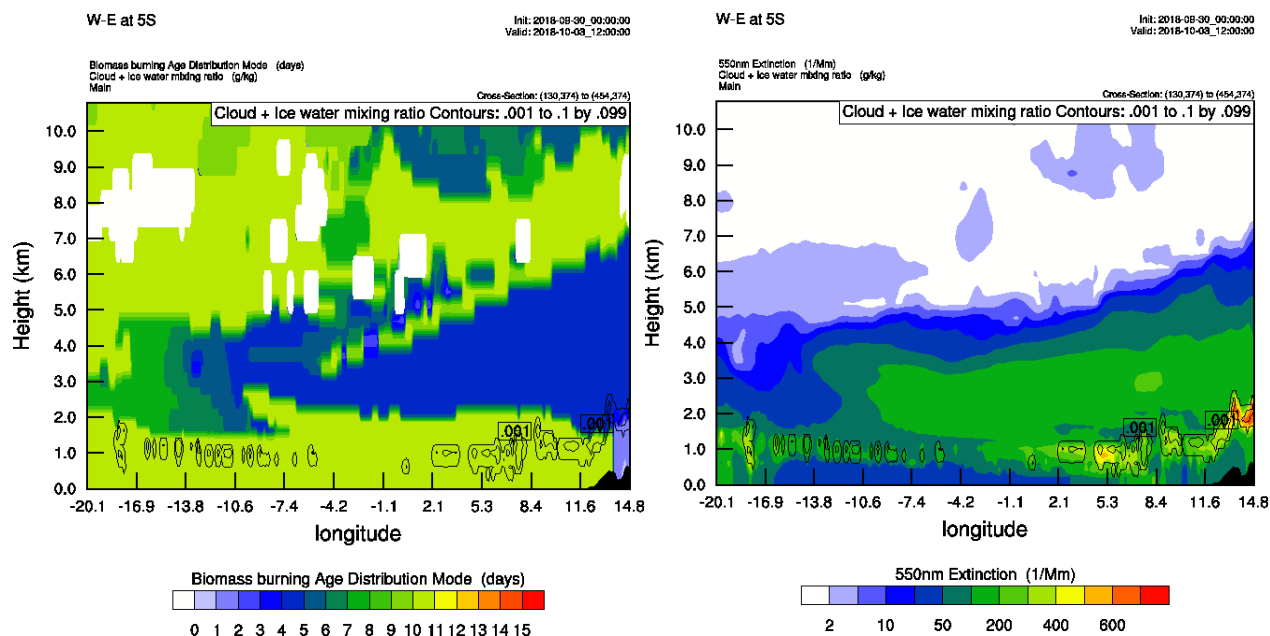


Figure 11: Short term forecasts (valid at 12 UTC on 10/03) from WRF-AAM for the modal age (left) and extinction (right) for W-E cross-section along 5S. This compares well with the measured extinction (Fig. 6, left), which, at 7E has peak extinction at around 3 km altitude, and relatively low scattering immediately above the clouds from 1-2 km altitude.

Other Visuals:

12:00 UTC Cloud Droplet Number Concentration from LARC ORACLES MSG cloud products (Fig. 12) indicating very low concentrations within the region of the POC, consistent with observational estimates from the cloud probes on the P-3.

Figure 12: Cloud droplet concentration estimate from SEVIRI for 12 UTC on 10/03/2018. Note the very low values ($10\text{-}30\text{ cm}^{-3}$) in the region of POC sampling (6.5-7.5S, 7E), with somewhat higher values in the overcast clouds to the north (around 5S) and also in the closed cells to the west (west of 5E, from 8-10S).

